The photodetection of the In-, Sn-, and Te-doped Bi_2Se_3 nanoplatelets

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Abstract

The compound Bi_2Se_3 has a narrow band gap of 0.35eV with a rhombohedral crystal structure and is a unique material with the gapless surface-state and the insulating bulk. It is a potential material in the application of photodetection, FET, quantum computation, etc. Bi_2Se_3 has the layered structure composing of 5-atomic layers of Se^1-Bi-Se^2-Bi-Se^1 known as a quintuple layer (QL) with a thickness of around 1 nm. The main bonding type inside the QL is the covalent bonds, and the van der Waals force dominates the bonding between the QLs.

In this investigation, the pure Bi_2Se_3, and In-, Sn-, and Te-doped Bi_2Se_3 nanoplatelets (NPs) were synthesized by the thermal CVD process using horizontal quartz tube at 600℃ under the pressure of 2×10^{-2} Torr, using sapphire as the substrate. The FESEM images show the hexagonal-like morphologies of the NPs. The results of XRD, HRTEM, Raman, and XPS confirm the typical rhombohedral Bi_2Se_3. The photodetection of the pristine Bi_2Se_3 NPs shows that the photocurrent and the ratio of photocurrent/dark- current under UV- and under red-light are of the 4×10^{-11} and 23.8×10^{-14}A and 7.7 and 1, respectively, while the co-dopants of In and Sn enhance the photocurrent as well as the ratio of photocurrent/dark-current of the Bi_2Se_3 NPs under UV- and under red-light up to 52×10^{-11} and 3.5×10^{-11}A and 30.7 and 52.2, respectively. The proposed factors can be summarized as the following: (1) formation of the donor defects (${In^{3+}}_{V^0}$) and (${Sn^{4+}}_{Bi^{3+}}$), the acceptor defects (${V^0}_{Bi^{3+}}$) and (${Sn^{2+}}_{Bi^{3+}}$), and the neutral defect (${In^{3+}}_{Bi^{3+}}$), (2) the reduced optical band gap of the doped Bi_2Se_3 NPs, and (3) the similar melting point of the powder precursors.

[1] C. C. Wang, Investigations on the fabrication, structure, photocatalytic and optoelectronic properties of metal oxide (ZnO) and topological insulator (Bi_2Se_3) nanostructures, PhD thesis 2021, National Chung Hsing University, Taichung, Taiwan.
[2] C. C. Wang F. S. Shieu, H. C. Shih, Photosensing and Characterizing of the Pristine and In-, Sn-Doped Bi_2Se_3 Nanoplatelets Fabricated by Thermal V–S Process, Nanomaterials 2021, 11, 1352.